

Buckling instability of crown sealing

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Citation: [Physics of Fluids](#) **27**, 091112 (2015); doi: 10.1063/1.4931097

View online: <http://dx.doi.org/10.1063/1.4931097>

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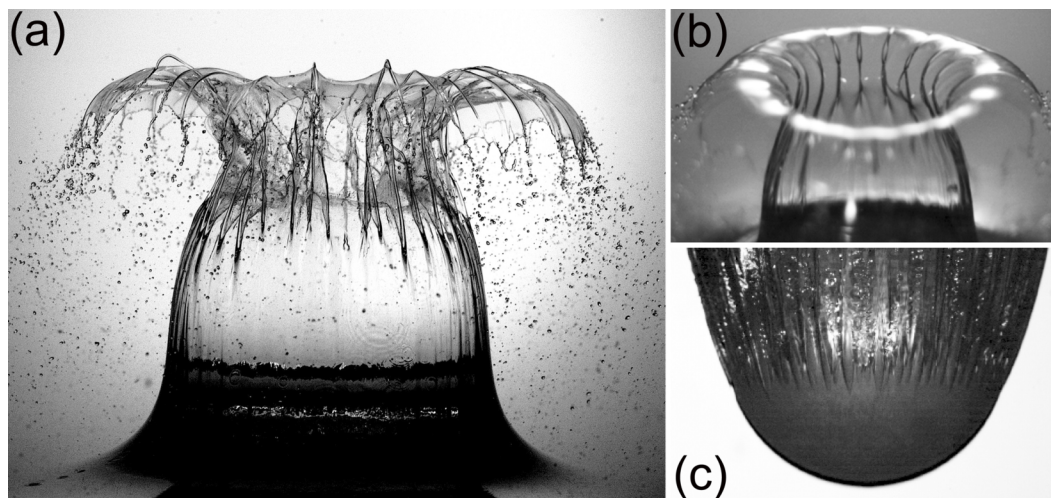


FIG. 1. (a) Side-view perspective showing the buckling instability of the crown during the water entry of a 10 mm steel sphere onto water-glycerol mixture. (b) Top-down view of the collapsing cavity. (c) Close-up view of the contact line, which is pinned around the equator of the sphere. Original video can be found online at <http://dx.doi.org/10.1103/APS.DFD.2014.GFM.V0073>.

Buckling instability of crown sealing

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(Received 2 September 2015; published online 24 September 2015)

[<http://dx.doi.org/10.1063/1.4931097>]

Despite the scholarly fascination with water entry of spheres for well over a century,¹ we present a new observation, namely, the crown-buckling instability. This instability is characterized by striations appearing near the top of the crown walls just prior to the surface seal, as shown in Fig. 1(a). The crown wall collapses inward due to the pressure differential across the wall created by the moving air in the wake of the sphere and surface tension within the crown. Since the rate of collapse is faster than that at which fluid drains out from the neck region, fluid collects into the striations and the crown buckles. The wall is slightly thicker along these striations than in between where the films are more susceptible to air flow and get drawn inward into the crown interior, thereby developing into bag-like structures (Figs. 1(a) and 1(b)) that ultimately atomize, causing a fine spray inside the crown. Under atmospheric conditions, this typically occurs within 5 ms after impact.

Utilizing a 6 m vacuum chamber, spheres were dropped through decreasing ambient pressures revealing that the dome over phenomenon can be significantly delayed, which in turn mitigates the buckling behavior (Fig. 2(a)). When present, however, we observe that the periodicity of the buckles can change as a function of diameter and surface tension. In particular, the number of buckles is proportional to the sphere diameter (Fig. 2(b)) but inversely proportional to surface tension (Fig. 2(c)). Surprisingly, the order of pinned contact line perturbations as shown in Fig. 1 did not correlate to the number of buckles even when their positions and number were intentionally altered (video online).



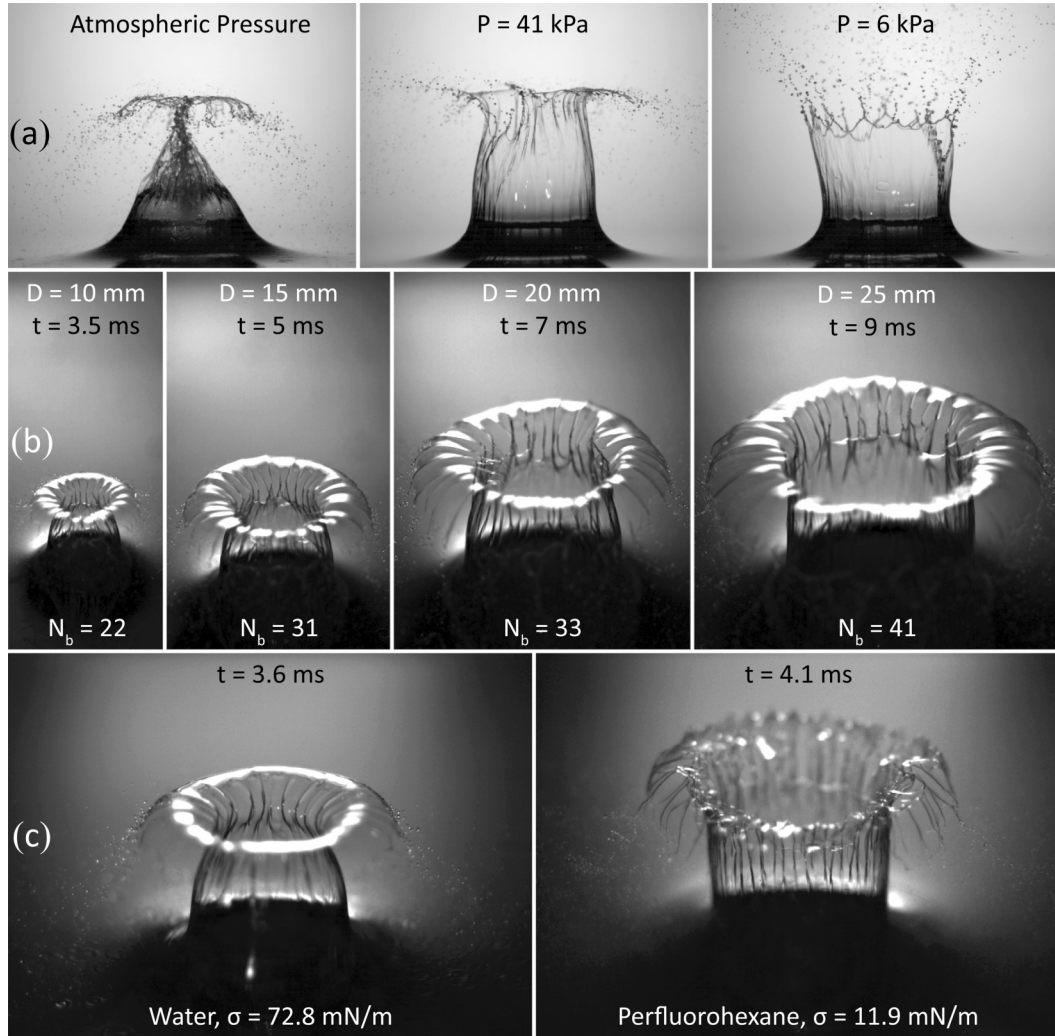


FIG. 2. (a) Three separate water entry cases of a 10 mm diameter sphere for decreasing pressures at $t = 5.1$ ms after impact. (b) Spheres with increasing diameters falling into a pool of water at atmospheric pressure where N_b represents the number of buckles in each case. (c) Impact events of a $D = 10$ mm sphere at atmospheric pressure for two different values of surface tension. The impact speed is $V = 10$ m/s for all cases.

We gratefully acknowledge support from the KAUST Office of Competitive Research Funds.

¹ A. M. Worthington, *A Study of Splashes* (Longmans, Green, and Company, 1908).